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Technical Note: Error in Olivier and Pineau's Regression Formulae for Calculation of Stature and Lunar Age From Radial Diaphyseal Length in Forensic Fetal Remains

ANGIE K. HUXLEY AND SUSAN B. JIMENEZ
Human Identification Laboratory, Arizona State Museum, The University of Arizona, Tucson, Arizona 85721 and Office of the Medical Investigator, University of New Mexico, School of Medicine, Albuquerque, New Mexico 87131

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ABSTRACT Stewart ([1979] *Essentials of Forensic Anthropology,* pp. 128–131) cites five regression formulae presented by Olivier and Pineau ([1960] Ann. Méd. Lég. *40:*141–144) for estimation of fetal stature from diaphyseal length. Of these formulae, one appears problematic: the formula for calculation of stature from the radius yields values which suggest the fetus has a much greater crown–heel (CH) length than do the remaining formulae for the diaphyses of other long bones. Moreover, when this stature estimate, so derived, is then inserted into these authors' earlier general formula for estimation of lunar age (Olivier and Pineau [1958] Arch. Anat. *6:*21–28) the error is compounded. A fetus is now indicated to be nearly a trimester older than when the CH lengths obtained by the other long bone formulae are used. Accordingly, we believe this particular formula, unlike the others, is incorrect and should not be used to estimate lunar age from fetal remains.

Calculation of gestational age from forensic fetal remains is problematic, since few studies have been conducted on these materials and these works are not readily available. Fazekas and Kósa (1978) published *Forensic Fetal Osteology* in Europe, but this reference is not easily obtained by scholars in the United States. Their work, however, is found in İşçan's (1989) *Age Markers in the Human Skeleton*, and this is considered a reliable source. Stewart (1979) published a widely used practical textbook, *Essentials of Forensic Anthropology,* which contains regression formulae taken from Olivier and Pineau (1958, 1960) for calculating stature and lunar age from fetal long bones. These formulae were recently used to estimate lunar age for comparison to Fazekas and Kósa's data in a forensic fetal case submitted to the Human Identification Laboratory, Tucson, Arizona. In the course of this work, a problem was noted. One of the four regression formulae, that for the radius, provided an age estimation 3 months in excess of the others. While scholars would utilize as many available skeletal elements as possible to derive age, it is conceivable that a single radius may represent all of the osseus elements from a single case, and thus be the only source used to derive gestational age. In light of this event, these results could have important implications, not only in forensic sciences, but also in physical anthropology in general.

METHODS

Anteroposterior radiographs were made of the antebrachial and crural segments of a

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Address reprint requests Angie K. Huxley, M.A., Human Identification Laboratory, The Arizona State Museum, University of Arizona, Tucson, AZ 85721.

fetus, the only skeletal elements suitable for analysis in the remains submitted to this laboratory. Measurements were taken with sliding calipers from the diaphyses of the ulna, radius, tibia, and fibula. Stature was calculated from these long bones, per the formulae of Olivier and Pineau (1958, 1960). The values derived from stature were placed into the more general regression equation for gestational age. While calculations from the ulna, tibia, and fibula all provided an age of approximately six and a half lunar months, those from the radius indicated a greater CH length, and, indirectly, an age of nine lunar months. After reviewing the original second article by Olivier and Pineau (1960), we discovered that the regression formula for the radius yields markedly different (i.e., longer) stature than do all the other formulae, which give essentially consistent results.

Parenthetically, we noted Stewart (1979: 130) incorrectly cited the deviations from the mean given by the original authors in the case of the radius, but this small error is of no significance to the matter at hand. Stewart (1979) cites this formula as fetal stature = 13.8 radius − 2.85 ± 1.62 cm, while Olivier and Pineau (1960) published as taille foetale (cm) = 13,8 longueur du radius − 2.85 ± k 1.82 cm. The mean, however, and not the deviation is used in Stewart (1979: 131; see Table 2) to calculate lunar age.

TABLE 1. Regression formula found in Stewart (1979:130) as taken from Olivier and Pineau (1960)[1]

Fetal stature = 7.92 humerus − 0.32 ± 1.8 cm
Fetal stature = 13.8 radius − 2.85 ± 1.62 cm
Fetal stature = 8.73 ulna − 1.07 ± 1.59 cm
Fetal stâture = 7.85 fibula + 2.78 ± 1.65 cm
Fetal stature = 7.39 tibia + 3.55 ± 1.92 cm

[1]Stewart did not give the original authors' values for the femur.

TABLE 2. Table on fetal growth in centimeters found in Stewart (1979:131), obtained from Olivier and Pineau's (1958) regression formula for calculation of lunar age (logarithm of age in months = 0.01148 × stature in cm + 0.4258 cm)

Age in lunar months	Stature	Crown–rump length
4 1/4	17.65	11.60
4 1/2	19.81	13.17
4 3/4	21.88	14.65
5	23.80	16.05
5 1/4	25.64	17.39
5 1/2	27.40	18.67
5 3/4	29.08	19.88
6	30.69	21.05
6 1/4	32.23	22.17
6 1/2	33.72	23.24
6 3/4	35.15	24.28
7	36.52	25.27
7 1/4	37.85	26.23
7 1/2	39.13	27.16
7 3/4	40.37	28.06
8	41.58	28.93
8 1/4	42.74	29.78
8 1/2	43.84	30.59
8 3/4	44.97	31.39
9	46.03	32.16
9 1/4	47.07	32.91
9 1/2	48.08	33.64
9 3/4	49.06	34.35
10	50.02	35.05

RESULTS: THE DISPARITY IN CALCULATION OF LUNAR AGE

Shortly after WWII, the anatomists Olivier and Pineau announced means of determining stature and lunar age from fetal remains obtained in Europe. Their research (1958, 1960) is cited in Stewart (1979) and thus available (albeit secondhand) to anthropologists and forensic pathologists in the United States. Stewart gives a brief description of the original studies and the regression formulae that grew out of them (Table 1). Of the formulae for determining stature, the formula for the radius shows great disparity in results compared to the results derived from the formulae for other long bones.

While calculations from the ulna, tibia, and fibula all provided estimates of stature within a couple of centimeters of each other, calculations from the radius yielded an estimate of stature 12–13 cm taller than that from other long bones studied. Moreover, when these estimates were then used in Olivier's and Pineau's (1958) formula to derive lunar age from stature (logarithm of age = 0.01148 height + 0.4258 cm), and when inserted into Stewart's table (Table 2), the radius yielded an estimate of nine lunar months (Table 3), while the ulna, tibia, and fibula all yielded estimates of approximately six and a half lunar months.

DISCUSSION

Recognized works in forensic fetal osteology, such as Fazekas and Kósa (1978), are difficult to acquire. Minimal results from their work are published in İşçan (1989:21–54) and these tables provide comparable estimates for lunar age from the diaphyses, ex-

TABLE 3. Diaphyseal lengths used to calculate fetal stature and age in lunar months from Stewart (1979)

Long bone utilized	Measurements (millimeters)	Fetal stature (centimeters)	Age lunar months
Right ulna	40.5 mm	34.29 cm	(6.6) 6 1/2–6 3/4
Right radius	36.0 mm	46.83 cm	(9.19) 9–9 1/4
Right tibia	40.0 mm	33.11 cm	(6.4) 6 1/4–6 1/2
Right fibula	37.5 mm	32.22 cm	(6.25) 6 1/4

cluding the radius. Stewart (1979) cites the regression formulae from Oliver and Pineau (1958, 1960). These secondary sources provided welcome access to data on forensic fetal osteology that otherwise would be inaccessible to some scholars. İsçan's and Stewart's texts are widely available and commonly used references that are relied upon by forensic and physical anthropologists. We, however, urge caution in calculating lunar age from the radius by Olivier and Pineau's regression formulae for long bones, either as given in the original article or as articulated in Stewart. Whereas ulnar, tibial, and fibular diaphyseal lengths provide estimates of stature within a few centimeters of each other, radial diaphyseal lengths give CH lengths that are much greater—almost 50% greater—in the forensic case presently under study (Table 3). When placed into a general regression formula of Olivier and Pineau for calculating lunar age, this fetus is estimated to be 3 months older than when values obtained from other diaphyses were used.

Olivier and Pineau (1958, 1960) and Fazekas and Kósa (1978) have provided commonly used standards within the fields of physical anthropology and forensic medicine on forensic fetal osteology. Their findings are accepted with little criticism of their collection technique, analyses, and interpretation of data. It is worth noting that these scholars did not have access to firm gestational ages, but had to rely on crude lunar ages presumably derived from maternal history or crown–rump and CH formulae developed from findings of earlier scholars (see Hass's rule in Fazekas and Kósa, 1978:30). While using two sets of regression formulae (those for calculation of stature and those for the calculation of age) may not be the *best current* method of estimating lunar age from fetal remains, it is important to understand how lunar age is derived from the standards that are still currently used. Alternative types of gestational age standards, within obstetrics and gynecology and general medicine, come from intrauterine ultrasound studies (see Hill et al., 1989; Queenon et al., 1980) and from gross morphological measurements to assess biometrically low birth weight infants (see Amato et al., 1991).

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